Using digital formative assessments to improve learning in physics education

Chapter 7

Impact Statement

7.1 Impact statement

Formative assessments are effective interventions in science education for improving academic performance. These assessments are interventions that prompt students to think about problems or course material, and aims to provide information to the teacher and student about the extent to which the material has or has not been mastered. In recent decades, formative assessments have gained increased attention because research shows that they can improve student learning. But too often the way formative assessments should occur is not consistent with what actually takes place in daily teaching practice, since teachers do a lot based on their gut feeling. So is the situation with formative assessments in science courses. A large number of science teachers do not realize that the way an assessment is organized and the way feedback is given affect students' feelings and learning. The aim of this dissertation is to provide evidence on how the way feedback is provided affects anxiety, motivation to learn, metacognitive awareness, and short-term and long term-course understanding in physics courses.

This dissertation shows that formative assessments contain multiple prompts, with the number and variety of prompts depending on how teachers organize assessments. In a limited time for testing, a teacher may choose to provide teacher feedback only. Based on an experimental study in everyday physics classrooms, this dissertation demonstrates that repeated formative assessments reduce anxiety in physics and improve academic performance in physics compared to traditional teaching. This implies that repeated formative assessments can make students feel more at ease, which contributes to more academic performance. For this reason, we argue that substantial effects can be achieved in upper secondary school physics education when teachers have limited time (10 to 15 minutes per class) for formative testing.

If teachers have more time, they may choose to have students engage in peer discussions. The results in this dissertation show that teacher feedback, whether or not combined with peer discussions, positively affect learning gains in comparison with students who do not receive any kind of feedback. The largest learning gains occur when peer discussions are followed by teacher feedback. Students learn from peer discussions and do not simply copy the same answer of their more skilled or more dominant peer. We argue that students can

indeed learn from peer discussions. With this evidence in mind, this dissertation shows that students who receive teacher feedback combined with peer discussions increase their motivation and metacognitive awareness in comparison to students who do not receive any kind of feedback. More metacognitive awareness enables students to think about, understand, and monitor their learning; skills that are critical in learning sciences, such as physics. However, girls differ from boys, as girls increase their metacognitive skills and get more motivated through teacher feedback (whether or not in combination with peer discussions), while boys increase their metacognitive skills and motivation only through peer discussions combined with teacher feedback. Differential effects are also observed for students with different metacognitive skills, as low-metacognitive students benefit more from peer discussions on top of teacher feedback than high-metacognitive students. We conclude that teacher feedback alone might be insufficient for students to improve learning, but that additional teacher feedback remains important and should be given after peer discussions, as it is possible that students discuss incorrect ideas, or answer questions that are inconsistent with the ideas they discuss. For this reason, teachers should use formative assessments with SRS in conjunction with peer discussions and teacher feedback to engage students in deeper metacognitive monitoring and developing metacognitive skills.

With the results obtained, this dissertation provides knowledge to the existing literature on the effects of feedback strategies in formative assessments with SRS on students' science anxiety, motivation, metacognitive awareness and performance. It also contributes to the literature with the development of a conceptual framework that identifies relationships between factors that may be responsible for influencing metacognition. Teachers benefit from the studies in this dissertation, as they give them insight that formative assessments are more than just weekly assessments. These assessments increase students' motivation to learn and reduce students' anxiety; feelings that influence metacognition and academic performance. The studies provide teachers with evidence that easy to organize assessments have large learning improvements. Receiving feedback on concept questions, positively affects course understanding in the short term. The results imply large effect sizes for teacher feedback (d = 0.83) and for peer discussion combined with teacher feedback (d = 1.13), and show that students who receive feedback apply their acquired knowledge of the course content to similar questions compared to students who do not receive feedback. Both effect sizes are

equivalent to the effect size of receiving feedback from teachers, students and peers on how to solve problems more effectively (*d* = 0.95; Hattie & Timperley, 2007). Students who are daily formatively assessed and who receive feedback on their answers gain also more course understanding in the long term than students who do not receive these assessments and feedback on their answers. This long-term course understanding corresponds to an effect size of *d* = 0.34.

We are aware that the studies in this dissertation are only relevant if teachers take note of the results and actually apply the findings in their classes. We have tried to keep our own studies close to everyday educational practice. In this way, we show that by brief formative testing every lesson or every week, the quality of teaching and learning can be increased. As stated previously, we recommend that teachers (1) make peer discussions a regular part of formative testing, and (2) use isomorphic questions that assess concepts in different contexts. The latter means that teachers should have a broad database of questions. This can be problematic, as creating enough questions takes a lot of time and expertise. It is an issue that schools themselves can take up, but it is also conceivable that this is a task for the Ministry or for publishers. However, cooperation between the various stakeholders and schools or teachers is important in this process, as the quality of formative assessments (and thereby teaching and learning) also depends on the quality of the questions.